THE EFFECT OF FORMAT VARIATION ON DATA ENTRY SPEED AND ACCURACY FOR THE MARINE INTEGRATED FIRE AND AIR SUPPORT SYSTEM (MIFASS)

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THESIS

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ABSTRACT

The purpose of this thesis is to determine if format variation has any affect on speed and accuracy of data entry for the Marine Integrated Fire and Air Support System (MIFASS).

Independent variables for the test are message formats, message types, and subjects. Subject learning effects and experimenter differences are controlled by use of a pilot study. Subjects are included as a treatment in order to estimate their effects.

The experiment is designed to support both parametric and nonparametric analyses. A 4×5×8 randomized complete block factorial with two replications is used to analyse the effects of format variation. Friedman's Two-Way ANOV by Ranks is used to test subjective rankings of the formats as concerns ease of use and operational suitability.

It is concluded that format variations do affect speed of data entry but not accuracy. Format 3 appears to be superior. Recommendations for further study are given.

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I. STATEMENT OF THE PROBLEM

A. THE PROBLEM IN GENERAL

The primary function of a Fire Support Coordination Center (FSCC) at any level of command is to provide the commander with the means for planning and coordinating available fire support. Specific responsibilities of a FSCC include fire support planning, designation of targets and assignment of priorities, allocation of fire support resources, and coordination of supporting arms with each other and the supported force. At present, all these responsibilities and functions are carried out manually through the use of radio and telephone communications, personal liaison, and an immense amount of paperwork. An inordinate amount of valuable time is lost in the FSCC during normal operations because of the paperwork and liaison required to accomplish its mission. In an attempt to eliminate this bottleneck and more effectively use the skill and training of the personnel who operate the FSCC, the Marine Corps, in conjunction with Hughes Aircraft Company, is developing an automated system which will materially reduce the paperwork, list keeping, and manual labor presently required in a FSCC. The system will be called the Marine Integrated Fire and Air Support System (MIFASS).

B. OVERVIEW OF THE AUTOMATED FSCC

The concept for MIFASS operations offers extensive improvement in tactical effectiveness through automation of fire request planning, fire support coordination, fire and air support planning, conflict prediction, and the consolidation of many other common functions at the MIFASS centers. The automated system will utilize various configurations of the hardware listed in Table I at designated levels of the operational tactical unit. Subunits operating under tactical control of the MIFASS centers will input intelligence data, fire support requests, med-evac requests, damage assessment reports, etc., to the MIFASS computer. MIFASS software will provide rapid response to many on-line users by interleaving the processing tasks and overlapping the input/output (I/O) demands with processing. Through generalized data management software, the system will permit definition of new messages, files, reports, and displays in the field without reprogramming. The application programs envisioned will include computer assistance and algorithm development for major requisite functions such as fire mission analysis, target data listing, air support control, technical fire control, conflict detection, troop safety, mission scheduling, resource allocation, etc. Since each FSCC will have access to the memory bank and coordinating agencies will be able to view the same data simultaneously on their own output units, the time needed to perform the required functions for all subunits will be materially decreased thereby increasing the effectiveness of the

overall system. Due to the probability that several agencies will be viewing the same data simultaneously and in the interests of simplification in training and programming, it is evident that a simplified and uniform data I/O procedure will be required.

TABLE I

HARDWARE REQUIRED FOR A FIELDED MIFASS

Each FSCC will employ a specific configuration of some or all of these units.

- Digital Message Entry Device (DMED)
- Portable Printer
- Remote Terminal Device (RTD)
  - Cathode Ray Tube (CRT) Display
  - Small Auxiliary Memory
  - Hard Copy Printer
  - Keyboard Entry Panel
  - Communications Net
- Computer with Internal Memory 16-131K
- Auxiliary Mass Memory 500K-8M Characters
- Magnetic Tape Units
- Printers
- Plotters
- Large Screen Displays
- Textual/Tabular Displays
- Graphic Displays

C. DATA ENTRY PROCEDURES

Proper data I/O procedures are crucial to the functioning of an automated system. One phase of these procedures which presents a potential bottleneck to the system is the format used when entering data or outputting it on a grid display or copier for viewing by interested parties. If a uniform format is not used by everyone, users will encounter problems in data retrieval and in interpretation of data entered by other on-line units. The requirement for a format (or formats) understood by all which is fast, accurate, and convenient is obvious. Determining the feasibility of such a format was the overall objective of this experiment.

D. PURPOSE OF THE TEST

As one approach to determining the feasibility of a uniform format for use in the system, this test was designed to evaluate differences in operator data entry speed and accuracy resulting from the use of alternative message formats when used with differing types of I/O data. The convenience and operational suitability of the formats tested was to be determined through operator surveys.

E. HYPOTHESES THAT WERE TESTED

H_{o1}: There is no significant difference in the speed of data entry due to the use of different message formats.

H_{o2}: There is no significant difference in the accuracy of data entry due to the use of different message formats.

H_{o3}: There is no significant difference in the speed of data entry due to the use of different message types.

H_{o4}: There is no significant difference in the accuracy of data entry due to the use of different message types.

H_{o5}: There is no significant difference in the speed of data entry due to the subjects used for the test.

H_{o6}: There is no significant difference in the accuracy of data entry due to the subjects used for the test.

H_{o7}: There is no significant interaction between message type and format for speed of data entry.

H_{o8}: There is no significant interaction between message type and format for accuracy of data entry.

H_{o9}: There is no significant interaction between message format and subject for speed of data entry.

H_{o10}: There is no significant interaction between message format and subject for accuracy of data entry.

H_{o11}: There is no significant interaction between message type and subject for speed of data entry.

H_{o12}: There is no significant interaction between message type and subject for accuracy of data entry.

H_{o13}: There are no significant interactions among message type, message format, or subject for speed of data entry.

H_{o14}: There are no significant interactions among message type, message format, or subject for accuracy of data entry.

H_{o15}: The subjects are indifferent to the message formats concerning ease of use.

H_{o16}: The subjects are indifferent to the message formats concerning operational suitability.

F. ASSUMPTIONS

1. Message Types

The message types selected for this experiment were assumed representative of the total population of messages envisioned for use in an operational MIFASS. The messages chosen varied in length from 62 to 573 characters which were a mixture of numeric and alpha-numeric; therefore, they covered a wide span of the total population.

2. Subjects

The subjects used for this test were assumed representative of the total population of personnel available to operate a fielded system. This assumption might be questioned in view of the experience and proficiency gained by the subjects during the preceding several months of system development. However, circumstances dictated that these particular subjects be used, and, in any case, it is a certainty that personnel assigned to operate a fielded system will undergo several weeks of intensive training before being permitted to begin actual operational duties. Thus, this assumption was considered justified.

3. Message Format Effects

Effects of different message formats on the speed and accuracy of data entry under test conditions were considered typical (ignoring stress, fatigue, etc.) of the effects which will be prevalent during actual operations.

If it is subsequently determined that any conditions make this assumption invalid, this experiment can be repeated under those conditions during later phases of MIFASS development.

G. GENERAL APPROACH

1. The Test

Four test runs were made, each of which consisted of a group of subjects entering data from five message types into a specific blank message format which was presented on a grid display screen. Each subject entered data twice for each message type for a total of 10 trials per run per subject. Speed and accuracy measures were taken for each trial. Upon completion of each run, the subjects each completed a subjective evaluation form concerning the ease of use and operational suitability of that format.

2. The Analysis

A randomized block factorial analysis of variance was used to test the first 14 hypotheses. The two subjective hypotheses were tested using nonparametric test procedures.

3. Remarks

It was not the objective of this experiment to choose a single format for use in a fielded system but to test the feasibility of such a format. However, if one of the formats tested were to be found faster and more accurate than the others under all test conditions, it might be assumed

that that format would be a good possibility for adoption as a universal format for the MIFASS.

II. SELECTION OF DESIGN

A. DEPENDENT VARIABLES

1. Speed of Data Entry

The time, T_i, required to enter each stimulus message into a blank message format was collected for each subject during each experimental run. This response was then normalized by dividing each T_i by the total number of keying actions required for that message format including any header data or spaces over which the operator had to space or tab manually. Thus, the dependent variable speed in this test was the normalized data entry time.

2. Accuracy of Data Entry

The accuracy of data entry was defined in terms of data elements which are entire sets of one or more characters to be entered into a single message field. The number, A_i, of data elements that had been entered incorrectly was collected for each message entered by each subject during each experimental run. Any error such as single or multiple typographical errors within a data element, an omitted data element, or one data element substituted for another was counted. This response was normalized by dividing A_i by the total number of data elements that were entered in the i^{th} message. Thus, the dependent variable accuracy in this test was the normalized data entry accuracy score.

3. Subjective Rankings

To forestall the possibility that individual memories might affect the ranking of the formats if the subjective opinions were to be gathered after all the formats had been presented, it was considered necessary to gather a separate opinion from each subject for each format immediately after it had been tested. A graduated interval scale was designed for each subjective dependent variable. Each scale consisted of 20 intervals with the endpoints and some intermediate intervals marked with verbal descriptions for ease in marking as shown in Fig. 1. These scales were then used for gathering the individual opinions.

a. Ease of Use

The graduated scale used by each subject to give his opinion of the ease of use of each format was marked from 0 to 20 where 0 coincided with the rating "Easy to Use" and 20 matched "Unusable."

b. Operational Suitability

The opinions for this subjective dependent variable were marked on a graduated scale where 0 coincided with "Very Suitable" and 20 with "Very Unsuitable."

B. INDEPENDENT VARIABLES

1. Message Formats

The independent variable of primary interest was message format. There were four different formats tested in this experiment. Appendix A presents the actual formats tested for each message type.

SUBJECT REACTION FORM

Subject ____________________ Format ____________________

Experimenter ________________ Date ____________________

Please indicate your reaction to the format you have just completed testing by placing a checkmark at the appropriate place on the line below.

1. How easy or difficult was it to use this format?

0	5	10	15	20
Easy to Use	Convenient	Useable	May be Useable	Unuseable

2. How would you rate this format as far as suitability for use in an operational MIFASS?

0	5	10	15	20
Very Suitable	Suitable	Possibly Suitable	Unsuitable	Very Unsuitable

Figure 1. Subject Reaction Form. This form was used to gather data necessary to the nonparametric analyses required.

a. Linear Format

In this format, each field name in the message was immediately followed, on the same line, by a space or spaces in which the pertinent message data for that field was to be entered. One field followed the previous field on the same line without spacing between fields until that line was filled. The succeeding fields were positioned in lines as stated until the entire message had been completed.

b. Block Format

The block format had the field names in a linear sequence with the message data space or spaces immediately below the field name on the next line of the display field. The field names were separated sufficiently to preclude information overlap in the message data spaces below. No space appeared between the line of field names and the line containing related message data. A double space appeared between each adjacent pair of lines. This form was followed until enough line pairs appeared to complete the entire message.

c. Columnar/Separated Format

For this format, all field names appeared in a single column on the left side of the display area. The space or spaces for the pertinent message data for each field appeared in a second column indented from the left margin of the display area, not from the end of the field name. Thus, the message data column appeared as a distinct column with a uniform margin.

d. Columnar/Run-On Format

This format had the field names in a column as above, but the space or spaces for message data appeared without spacing to the immediate right of the field name. Instead of a single column of field names-message data as used above, three columns were used where space on the display area existed; otherwise, two columns were used.

2. Message Types

An independent variable of secondary interest was message type. As previously discussed, the five types selected for this experiment were assumed to be representative of the total population of messages to be found in a fielded system. Data pertinent to these message types is shown in Table II. The actual messages used form Appendix B.

TABLE II

DATA ON MESSAGE TYPES

Msg. Type	Msg. Name	Msg. Name	Number of Characters	Number of Fields
1	CHKFIM	Check Fire Command	62	6
2	EOMBDM	End of Mission Battle Damage Assessment	96	10
3	TGTLST	Target List Input	151	14
4	CFFTGR	Call for Fire by Target Number	266	23
5	FORDRM	Fire Order Universal	573	54

3. Subjects

The other independent variable of secondary interest was the subjects participating in the test. As discussed, these subjects were assumed to be representative of the total population of potential system operators. However, their previous training and experience might have affected their performance and might have introduced bias into the experiment. The inclusion of subjects as treatments permitted an analysis of their effects on the dependent variables to be made. Eight subjects were used.

4. Replications

The independent variable of tertiary interest was replication. The inclusion of this variable was principally to provide a check to see if the experiment was conducted consistently.

C. CONTROLLED VARIABLES

There were several nuisance variables which had the potential to bias the outcome of the experiment. Subjects were such a potential source of bias and their effects were controlled by including them as a treatment in the experimental design. Other nuisance variables could not be experimentally controlled as were subjects but had to be controlled by other means.

1. Abbreviations and Acronyms

This source of bias was controlled both experimentally and statistically. The use of abbreviations and acronyms in

all message types is not necessarily proportional to the length of the message; therefore, the normalization of the dependent variables as discussed in Para. II.A was also utilized to statistically control this effect by keeping the variation more nearly constant over the normalized data base. Standard abbreviations and acronyms were used for all message types for all formats. This assumption held these effects constant.

2. Experimenter Differences

Two experimental controls were used to minimize effects due to potential experimenter differences. First, all experimenters were trained to administer the experiment in a standard fashion thus minimizing effects due to different testing procedures. Second, each experimenter presented each format twice and administered no more than one test run to any given subject.

3. Subject Learning Effects

To minimize learning effects, two experimental controls were used: training and randomization of presentation of formats. All subjects completed the Marine Tactical Command and Control System (MTACCS) Test Bed Operations Training Course prior to being administered the test. Such training ensured familiarity with all five message types and all four formats. Thus, when proceeding from a test run with one format to the next run with another, a subject's learning effects were minimized. Remaining effects which could possibly introduce bias were reduced by randomizing

the order of presentation of the formats and message types to the subjects.

4. Stimulus Presentation

a. Message Input Stimuli

The stimulus messages were presented in hard copy form only. Radio or voice presentation was deemed too difficult to control with the facilities available for the test. See Appendix B.

b. Format Stimuli

The formats used for this test were presented to the subject on the grid display screen. One format was presented at a time in the order shown in Table III. The random ordering of the presentation of each format minimized any possible effects from subject learning that could have occurred if the formats had been presented to all the subjects in the same order.

D. STATISTICAL DESIGN

Since it was desired to secure data from every combination of the independent variables, a randomized complete block factorial design, $4 \times 5 \times 8$ with two replications, was selected for this experiment. This design required 320 data points with which to test the hypotheses and provided an extremely high power for the test. Table III presents the test schedule required to support this design.

TABLE III

TEST SCHEDULE

	S_1 F	S_1 T	S_2 F	S_2 T	S_3 F	S_3 T	S_4 F	S_4 T	S_5 F	S_5 T	S_6 F	S_6 T	S_7 F	S_7 T	S_8 F	S_8 T
		5		4		4		3		3		2		4		5
		4		1		5		1		1		4		5		1
		3		2		1		4		4		1		4		2
		2		3		1		1		5		3		2		5
Run 1	2	3	2	5	4	2	4	2	1	3	1	4	3	2	3	4
		4		2		3		5		5		5		3		2
		1		1		4		4		4		2		5		3
		2		3		2		5		2		1		1		3
		1		5		3		3		1		5		1		4
		5		4		5		2		2		3		3		1
		E_3		E_4		E_1		E_2		E_3		E_4		E_1		E_2
		1		4		4		4		5		5		2		2
		5		5		1		4		5		2		4		3
		1		5		4		5		3		4		5		5
		3		3		2		5		4		1		1		5
Run 2	3	5	3	2	1	2	1	2	4	3	4	3	2	2	2	1
		2		3		5		3		1		4		1		2
		4		1		5		1		2		2		5		1
		4		4		3		2		4		5		3		3
		2		2		1		1		2		1		4		4
		3		1		3		3		1		3		3		4
		E_4		E_3		E_2		E_1		E_4		E_3		E_2		E_1
		4		3		3		5		1		2		4		1
		2		5		5		2		2		3		3		1
		4		4		2		3		1		4		2		5
		3		5		4		1		3		5		1		2
Run 3	1	5	1	2	2	4	2	4	3	2	3	2	4	3	4	4
		3		4		3		4		3		5		4		3
		5		1		1		5		4		1		5		3
		2		2		5		2		4		1		5		2
		1		3		2		3		5		3		2		4
		1		1		1		1		5		4		1		5
		E_1		E_2		E_3		E_4		E_1		E_2		E_3		E_4

TABLE III (Cont.)

	S_1		S_2		S_3		S_4		S_5		S_6		S_7		S_8	
	F	T	F	T	F	T	F	T	F	T	F	T	F	T	F	T
		5		3		1		5		5		4		3		2
		3		4		2		2		1		2		2		5
		4		5		5		2		3		1		3		3
		2		4		5		3		3		5		5		1
Run 4	4	3	4	2	3	3	3	4	2	5	2	3	1	2	1	5
		1		5		2		5		1		3		5		4
		2		3		3		4		2		5		1		4
		1		1		1		1		4		4		4		1
		4		2		4		1		2		2		1		3
		5		1		4		3		4		1		4		2
		E_2		E_1		E_4		E_3		E_2		E_1		E_4		E_3

1. Assumptions

a. Model

The mathematical model assumed for this design was a fixed factor model as developed in Ostle [Ref. 1]:

$$X_{ijkl} = u+R_i+A_j+B_k+C_l+(AB)_{jk}+(AC)_{jl}+(BC)_{kl}+(ABC)_{jkl}+e_{ijkl}$$

where X_{ijkl} = observation ijkl

u = mean effect (constant)

R_i = effect of replicate i, i=1,2

A_j = effect of message format j, j=1,2,3,4

B_k = effect of message type k, k=1,2,3,4,5

C_l = effect of subject l, l=1,2,...,8

$(AB)_{jk}$ etc. are interaction terms

e_{ijkl} = random error for observation ijkl

It was assumed that e_{ijkl} was distributed normally with mean zero and variance σ^2 where e is homoschedastic for all i,j, k, and l. It was further assumed that there were no replication by treatment interactions and that the observations were independently distributed multivariate normal.

b. Treatment Effects

As discussed, all factors in this model were assumed to be fixed. There is no doubt of this for the formats and message types; however, the subject sample might be argued to be random rather than fixed. Considering the experience gained by all the subjects through several months familiarization with the test bed and its equipment and their overall level of past Marine Corps operational experience and training, it was decided that generalization of the conclusions made from this test over the entire population of possible field operators would not be totally valid. Therefore, of necessity, this factor had to be considered fixed, also.

c. Effects of Nonconformity to Assumptions

In general, the consequences are not serious when the assumptions made in connection with the analysis of variance are not strictly satisfied. For example, minor deviations from normality and/or some degree of heteroschedasticity will have little effect on the usual tests and

the resulting inferences. Reference 2 discusses this aspect of experimental design thoroughly.

2. <u>Sample Size</u>

To determine the proper sample size to use for this test, one has to use ideas developed by Tang [3] and used by Pearson and Hartley [4] in the development of their power function curves. Using these developments, one calculates the sample size required to yield a specified power for the desired test utilizing this equation:

$$\phi = \frac{\sqrt{\dfrac{\Sigma_i D_i^2}{k}}}{\sigma/\sqrt{n}}$$

where ϕ = power function

D_i = difference between the effect of the i^{th} treatment and the mean effect of all treatments

k = number of treatments (i.e., number of levels of the treatment in question

σ = standard deviation of errors

n = number of observations required for each treatment level

Since, for this experiment, σ and D_i were not known, a modification to this equation was made to circumvent these problems. It was assumed that a maximum detectable treatment difference of one σ about the mean would be sufficient for this experiment. It can be shown that the minimum $\Sigma_i D_i^2$ occurs when two of the treatment differences are $-\frac{\sigma}{2}$ and $\frac{\sigma}{2}$ and the remaining differences are 0 [Ref. 7]. Then

$$\Sigma_i D_i^2 = \left(-\frac{\sigma}{2}\right)^2 + \left(\frac{\sigma}{2}\right)^2 + 0 + \ldots + 0 = \frac{\sigma^2}{2}$$

Hence, if the maximum detectable difference is other than that chosen, the power of the test will increase. Now, the above equation for ϕ becomes

$$\phi = \frac{\sqrt{\frac{\sigma^2}{2k}}}{\sigma/\sqrt{n}} = \sqrt{\frac{n}{2k}}$$

This form was much simpler to utilize and was no longer sensitive to errors in estimating σ. Using this power function with the proper degrees of freedom and $\alpha = 0.05$, the available power can be determined for various sample sizes from the curves produced by Pearson and Hartley [4]. As shown in Table IV, a power of approximately 0.90 was attainable for the test of format differences with as few as three subjects, each subject using two samples of each message type for each format; whereas, four subjects were required to get a similar power for the test of message types. Since there were 40 observations for each subject, effects of subject differences could be tested with extremely high power for almost any number of subjects. However, as the use of eight subjects did not add materially to the cost or time required but did enhance the power of any test desired, eight subjects were used.

TABLE IV

AVAILABLE POWERS FOR THE TEST

No. of Subj.	Obs./Subj./ Cell	Degrees of Freedom for Error Term	Power	
			Format	Msg. Type
12	2	239	0.999	0.999
10	2	199	0.999	0.999
8	2	159	0.999	0.999
6	2	119	0.999	0.982
4	2	79	0.972	0.890
4	3	158	0.999	0.984
3	2	59	0.895	0.770
3	3	118	0.986	0.950
2	2	39	0.710	0.550
2	3	78	0.910	0.790
2	4	117	0.968	0.900

III. LOGISTICS AND TRAINING

A. SUBJECTS

The eight subjects used for this test were Marine Corps officer and enlisted personnel assigned to the MTACCS Test Bed which has direct responsibility for developing MIFASS. Names of 22 eligible officers and men formed a pool from which eight were drawn randomly to act as subjects. Prerequisites for eligibility were previous training or experience in fire support coordination, artillery coordination, target data analysis, and test bed operations. A capability of an extremely high or low typing speed rendered potential subjects ineligible as it was desired to have typing speed on a level representative of personnel who will serve in a fielded MIFASS. Each subject had completed the MTACCS Test Bed Operations Course which covered those subjects listed in Table V. Prior to their first test run, the subjects were thoroughly briefed on the experiment.

B. EXPERIMENTERS

The four experimenters necessary for this test were selected similarly to the subjects except that all test bed personnel, including the civilian contractor employees, were considered eligible for duty as experimenters. Availability was the prime consideration in experimenter selection. Those selected were familiar with MTACCS Test Bed operations through the above mentioned course and were all

TABLE V

SUBJECTS COVERED IN THE MTACCS TEST BED OPERATIONS COURSE

MTACCS Concept
Role of the Test Bed
MIFASS TSM Concept
Concept of Test Bed Operations
Display and Entry Devices (I/O) (Included practical exercises)

Marine Corps personnel. Additional training included experiment familiarization sessions conducted by the test administrator, practice sessions, and a pilot study as discussed in Para. IV.A. Those selected also attended the subject briefings.

C. HARDWARE AND SOFTWARE REQUIREMENTS

1. Hardware

The hardware listed in Table VI was utilized for the performance of this experiment.

2. Software

The software used for this experiment is discussed thoroughly in Ref. 5. Since it is not in the public domain nor pertinent to a general discussion of the test, a listing is omitted here.

TABLE VI

HARDWARE REQUIRED FOR THIS EXPFRIMENT

Unit	Model	Quantity
CDC Computer System	3300	1
CDC Grid Display System	243-1	1
Call Director	600	2
Voice Recorder	TR-1720	1
Time Code Generator	TC-201	1

D. TEST EQUIPMENT AND MATERIAL

1. Subject

In order for the subjects to function efficiently, they had at their disposal on the grid display console a reference chart and a MTACCS Glossary. The reference chart contained field header data and allowable field data entries used in all MIFASS messages and displays. The MTACCS Glossary contained all the abbreviations and acronyms to be used.

2. Experimenter

Each experimenter had at his disposal the following items: a stopwatch, Parametric Data Collection Forms, Subject Reaction Forms, the voice recorder, and the input message stimuli.

E. STIMULUS MATERIAL

All stimulus materials were developed by Hughes Aircraft Company in conjunction with Test Bed officers. Message input stimuli for the five messages used appear in App. B. The formats presented to the subjects for each message appear in App. A.

F. DATA COLLECTION FORMS

To support the analyses necessary for this test, two data collection forms were necessary.

1. Parametric Data Collection Form

As depicted in Fig. 2, this form was used to collect data for use in determining speed and accuracy measures. One form was completed by the applicable experimenter for each subject for each format. A total of 32 forms were required.

2. Subject Reaction Form

As discussed earlier, this form was necessary as an intermediate step in the nonparametric analysis. A total of 32 forms were required as each subject completed one for each format immediately upon completion of the run testing that format. Figure 1 depicts this form.

Subject ______________ Date ____________________

Format ______________ Experimenter _____________

Message Type	Time	No. of Errors	Remarks

Experimenter Notes

Figure 2. Parametric Data Collection Form. This form was used to gather speed and accuracy data for the ANOV.

IV. TEST PROCEDURE

A. PILOT STUDY

1. Purpose

The pilot study was primarily conducted in order to validate the test design, determine if the desired data could be collected, and see if the required analyses could be made using this data. Secondary considerations were training of experimenters, refinement of data collection procedures and forms, and detection and correction of errors in the test stimuli.

2. Administration

a. Materials

The test stimuli, equipment, and data collection forms used were those to be used during the actual test.

b. Procedure

The test administrator selected those individuals to be used as experimenters during the test. Trial runs were made with each selectee acting as the subject to familiarize him with the entire test. Each selectee then performed as an experimenter for other runs using another experimenter as a subject. Data was collected as it was to be collected during the actual test. This procedure was followed until the test administrator felt that the level of experience was great enough to minimize any effects due to experimenter differences.

c. Results

A trial analysis was made using the data gathered during the pilot study. The test design was confirmed as was the suitability of the data collection forms.

B. TEST PROCEDURE

The actual test runs were conducted as follows:

Prior to each run, the test administrator ensured that the system was operating properly and that the correct software was loaded.

The experimenter presented the subject with the proper message stimuli and recorded the event on the voice recorder.

The format to be filled in by the subject was called to the screen from the memory.

When the format to be tested appeared, the experimenter recorded the event and started his stopwatch.

The subject entered the necessary data using the alphanumeric keyboard on the grid console.

Upon completion of his task, the subject pressed the STORE RECORD key. The experimenter stopped his stopwatch and recorded the time on the voice recorder and the Parametric Data Collection Form.

The above steps were repeated until that run was complete. The subject then completed his Subject Reaction Form.

C. SUBJECT BRIEFING

Prior to commencement of the first test run, a thorough briefing was given to all subjects and experimenters. The briefing served to acquaint the subjects with the test, its purpose, and its procedures. The test administrator previewed the test, answered any questions the subjects or experimenters had, and provided each subject with the test schedule. The subjects were cautioned not to discuss their reactions with other subjects until after completion of the entire test.

V. ANALYSIS

A. PARAMETRIC ANALYSIS OF VARIANCE (ANOV)

1. Procedure

a. Data Collection

Test data for the dependent variables speed and accuracy were collected on the Parametric Data Collection Form. The time required to enter each message stimulus into each format by each subject was recorded by the experimenter but the accuracy observations were collected differently. Errors were detected through the use of a compare program by which the computer compared actual entries with the correct entries and provided a printout of all entries containing errors. The Test Administrator then manually counted and recorded these errors. The data collected for both parametric analyses is presented in App. C.

b. Normalization of Data

In order to preclude effects due to the differing lengths of the message types, the test data had to be normalized.

(1) Speed. The normalizing factors for speed of data entry were the reciprocals of the number of Keying actions necessary to enter a message type into a particular format. For example, for Format 1 Message Type 1, the number of keying actions required was 26, so the time for each subject to enter the data for this combination was

divided by 26 to obtain the normalized times. These times appear in App. D.

(2) Accuracy. The accuracy scores were normalized in a similar manner; however, the normalizing factors were the reciprocals of the number of complete data elements to be entered in each format for each message type. These normalized observations appear in App. D.

c. Organization of Data

In order to minimize the effort necessary for performing the ANOV for both speed and accuracy, the data in App. D was rearranged into interaction tables as shown in App. E [1].

d. Computations and ANOV Tables

The computations necessary for obtaining the results to be entered in the ANOV tables were accomplished using the set of equations summarized in Ref. 1. The general form of an ANOV table is discussed in Ref. 1, also; therefore, it will not be presented here.

2. Results

a. ANOV for Speed of Data Entry

The ANOV table obtained for the dependent variable speed in this test is given in Table VII. The effects of the different format levels and message types are significant at $\alpha = 0.05$ as are the interactions of format with both message type and subject. The acceptance or rejection of the hypotheses concerning speed of data entry is given below:

H_{o1}	Rejected
H_{o3}	Accepted
H_{o5}	Rejected
H_{o7}	Rejected
H_{09}	Rejected
H_{011}	Accepted
H_{o13}	Accepted

b. ANOV for Accuracy of Data Entry

Results obtained from the ANOV of the dependent variable accuracy are displayed in Table VIII. Significant effects are exhibited by formats, message types, and their interaction at $\alpha = 0.05$.

During the test, faulty design in the program for Message Type 2 entered in Format 1 required a data element to be carried over from one line to the next. The margin for the 80^{th} character on the grid screen was not visible so several subjects had difficulty determining when to cease entering data on the first line and to continue on the second. The higher incidence of errors for Format 1 and Message Type 2 made an adjusted ANOV for accuracy desirable. Therefore, another ANOV was conducted with the errors which were directly attributable to this programming problem omitted from the observations. Table IX displays the adjusted ANOV results. As shown, format and message type effects are no longer significant though their interaction remains so. For the two ANOV for accuracy of data entry, the acceptance or rejection of the hypotheses is:

TABLE VII

ANOV TABLE FOR SPEED OF DATA ENTRY

Source	df	SS	MS	F
Replications	1	.096	.096	1.215
Treatments				
Format (A)	3	2.330	.777	9.835*
Msg. Type (B)	4	.663	.166	2.101
Subject (C)	7	8.706	1.244	15.746*
AB	12	2.552	.213	2.696*
AC	21	3.311	.158	2.000*
BC	28	1.871	.067	.848
ABC	84	5.798	.069	.873
Error	159	12.613	.079	
Total	319	37.938		

*Significant at $\alpha = 0.05$. All others were tested against $\alpha = 0.05$ and were not significant.

TABLE VIII

ANOV TABLE FOR ACCURACY OF DATA ENTRY

Source	df	SS	MS	F
Replications	1	.00006	.00006	.03
Tr atments				
Formats (A)	3	.02679	.00893	5.02*
Msg. Types (B)	4	.03520	.00880	4.94*
Subjects (C)	7	.01167	.00170	.96
AB	12	.13266	.01106	6.21*
AC	21	.03989	.00190	1.07
BC	28	.05343	.00191	1.07
ABC	84	.11638	.00139	.78
Error	159	.28319	.00178	
Total	319	.69927		

*Significant at $\alpha = 0.05$. All others were tested against $\alpha = 0.05$ and were not significant.

TABLE IX

ADJUSTED ANOV TABLE FOR ACCURACY OF DATA ENTRY

Source	df	SS	MS	F
Replications	1	.00026	.00026	.17
Treatments				
Formats (A)	3	.01105	.00368	2.44
Msg. Types (B)	4	.00824	.00206	1.36
Subjects (C)	7	.01844	.00264	1.75
AB	12	.11210	.00934	6.19*
AC	21	.03085	.00147	.97
BC	28	.05538	.00198	1.31
ABC	84	.11288	.00134	.89
Error	159	.24037	.00151	
Total	319	.58957		

*Significant at $\alpha = 0.05$. All others were tested against $\alpha = 0.05$ and were not significant.

	Original	Adjusted
H_{o2}	Rejected	Accepted
H_{o4}	Rejected	Accepted
H_{o6}	Accepted	Accepted
H_{o8}	Rejected	Rejected
H_{o10}	Accepted	Accepted
H_{o12}	Accepted	Accepted
H_{o14}	Accepted	Accepted

B. NONPARAMETRIC ANALYSIS

1. Procedure

a. Data Collection

Immediately upon completion of each test run each subject completed a Subject Reaction Form on which he marked his evaluation of the ease of use and suitability of the format tested.

b. Analysis

The Friedman Test is discussed thoroughly by Conover and Kirk [Refs. 6 and 7]. It requires two assumptions (which are considered valid for this test): (1) each subject's evaluation of the four formats will be independent of every other subject's evaluation, and (2) a subject's evaluations may be ranked in some manner. The analysis for both ease of use and suitability is given in App. F.

2. <u>Results</u>

a. Ease of Use

The test statistic for this analysis was 15.96 which, when compared with the 0.95 quantile of a Chi Square random variable with three degrees of freedom, is significant.

b. Suitability

For this analysis, the test statistic was 11.64 which is also significant at the 0.05 level.

c. Hypotheses

Both H_{o15} and H_{o16} were rejected at the 0.05 level, i.e., the subjects were not indifferent to the formats as hypothesized.

VI. CONCLUSION

A. PARAMETRIC ANOV

1. Speed of Data Entry

The results of the ANOV for this dependent variable clearly show that format variation does affect speed of data entry; thus, the primary purpose of this test was successfully accomplished. However, due to significant interactions of the formats with both message types and subjects, interpretation of significant main effects must be qualified. Figure 3 illustrates the type of interaction detected between formats and subjects.

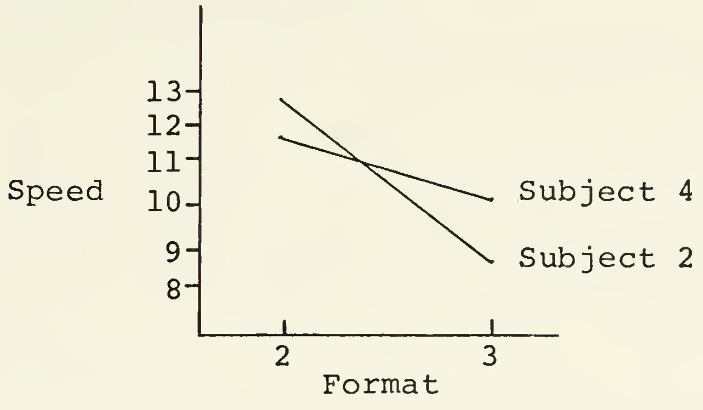

Figure 3. Example of a Typical Format-Subject Interaction.

It appeared that groups of subjects reacted in similar manners but that each group reacted differently from the other groups. For example, subjects 1,2,7, and 8 all reacted to the formats in the same order, i.e., Formats 4,3,1, and 2

(from fastest to slowest), whereas, Subjects 4,5, and 6 reacted in the order 3,4,2,1, and for Subject 3 the order was 2,3,1,4. No discernible pattern of subject characteristics such as I.Q., typing speed, test bed experience, MOS, etc., was evident within the groups. Though the subject levels were considered fixed, it may be concluded that no single format will be best for all the operators in a fielded system. For any format chosen, under the present concept, some operators will not be able to function optimally. This implies that rigid selection and training programs must be instituted in order to minimize the effects due to operator variations. The format-message type interaction implies that some message types are inherently faster (or slower) when entered in certain formats.

2. <u>Accuracy of Data Entry</u>

The original ANOV clearly rejected the hypothesis that neither format nor message type would affect accuracy of data entry. However, when ignoring those errors directly attributable to the program error, an adjusted ANOV resulted in the acceptance of these hypotheses. The results of the adjusted ANOV indicate that these factors have little effect on accuracy of data entry; however, their interaction is significant. This implies that some of the message types are inherently more accurate (or inaccurate) when used with certain formats.

B. NONPARAMETRIC ANALYSIS

Both hypotheses tested were rejected. The subjects tended to consistently rank the formats so that one or more were favored over the others. Viewing the totaled ranks for each format one may infer that the subjects tended to favor Format 3 over the others for both categories. In both cases the overall ranking of the formats was 3,4,1, and 2.

C. SUMMARY

1. Purpose of the Test

As discussed in Para. I.D, this test was designed to evaluate differences in operator data entry speed and accuracy resulting from the use of alternative message formats when used with differing types of I/O data. The test was not designed to determine which format would be best but to determine whether or not different formats would affect the dependent variables. To this extent, the purposes of this test were accomplished. Different formats do affect the speed of data entry but do not affect accuracy appreciably.

2. Inferences

Due to the format-subject interaction, no one format can be inferred with certainty to be superior to the others. However, the mean speed for Format 3 was the smallest of the four formats tested and its error rate was very low. It received no rank below two for ease of use and was considered first by four subjects and tied for first by one. Concerning operational suitability, Format 3 was ranked

first by four subjects and tied for first by one. It was definitely preferred over the other three formats tested by the majority of the subjects even though it was not fastest for several. Thus, Format 3 may be inferred, with reservations, to be superior for use in a fielded system.

D. RECOMMENDATIONS

As shown, the evidence tended to place Format 3 over the other three formats for use in the MIFASS. Further testing should be contemplated to determine the reasons for subject and message type effects. If subject effects can be overcome through selection and training of operators, then further development can be directed toward determining optimum formats for the message types to be used. This study can be integrated into the ongoing development of the entire system if time does not permit other tests to be conducted alone and proper precautions are taken to prevent confounding of variables. Another aspect to be approached is the weighting of message types with regard to their importance to the success of the system. If a particular message type is crucial to the success of the system, it should have more weight when optimal formats are being considered.

APPENDIX A: FORMATS USED IN THIS TEST

FORMAT 1: MESSAGE TYPE 1

```
CHKFIM;FR:    ;TO:    ;TGT NO:      ;RQNO:      ;DTG:XXXXXXXX;
```

MESSAGE TYPE 2

```
EOMBDM;FR:    ;TO:    ;TGT NO:      ;RQNO:      ;CAS:     ;%DEST:  ;ENMY PSTR:
  ;DTG:XXXXXXXX;
```

MESSAGE TYPE 3

```
TGTLST;FR:    ;TO:    ;GRID:             ;ALT:     ;TTYP:      /      ;SIZE:   X
M;ATT:  MIL;DOP:      ;QTY:     ;CLAS: ;PRI: ;STATUS:    ;DTG:XXXXXXXX;
```

MESSAGE TYPE 4

```
CFFTGR;FR:    ;TO:    ;TGT NO:      ;TTYP:      /      ;QTY:     ;SIZE:   X   M;
DOP:       ;TGT MOV:      ;AD:    ;DTOT:    ;ATT:  MIL;METH ENG:           ;WCAT:
   ;WPN:      ;ORD:       ;FZ:     ;DISTRB:    ;MOF:    ;MOC:        ;OT DIR:   MIL
;RQNO:      ;DTG:XXXXXXXX;
```

MESSAGE TYPE 5

```
FORDRM;FR:    ;TO:    ;WCAT:    ;TGT NO:      ;RQNO:      ;GRID:                ;
ALT:     ;MOC:        ;MOF:    ;METH ENG:           ;DISTRB:    ;OPN FIR:      ;
UADJ:             ;RDS:     ;ORD:       ;FZ:     ;LOT:  ;CHG: ;ANGLE:  ;TOT:       ;
UFFE:             ;RDS:     ;ORD:       ;FZ:     ;LOT:  ;CHG: ;ANGLE:  ;GTAZ:      ;
UFFE:             ;RDS:     ;ORD:       ;FZ:     ;LOT:  ;CHG: ;ANGLE:  ;GTAZ:      ;
UFFE:             ;RDS:     ;ORD:       ;FZ:     ;LOT:  ;CHG: ;ANGLE:  ;GTAZ:      ;
DTG:XXXXXXXX;
```

```
FORMAT 2: MESSAGE TYPE 1

CHKFIM.
 FR.    TO.    TGT NO. RQNO.    DTG:
:    ;:    ;:       ;:       ;:XXXXXXXX;


          MESSAGE TYPE 2

EOMBDM.
 FR.    TO.    TGT NO. RQNO.    CAS.    %DEST. ENMY PSTR. DTG.
:    ;:    ;:       ;:       ;:      ;:  ;    :    ;     :XXXXXXXX;


          MESSAGE TYPE 3

TGTLST.
 FR.    TO.    GRID.        ALT.    TTYP.           SIZE.     ATT.   DOP.       QTY.
:    ;:    ;:            ;:      ;:       /       ;:   X   M;:  MIL;:          ;:

  CLAS.   PRI. STATUS. DTG.
;: ;     : ;   :    ;   :XXXXXXXX;


          MESSAGE TYPE 4

CFFTGR.
 FR.    TO.    TGT NO. TTYP.          QTY.    SIZE.     DOP.    TGT MOV. AD.  DTOT.
:    ;:    ;:       ;:       /       ;:      ;:   X   M;:        ;:        ; :   ;:    ;

 ATT.   METH ENG.    WCAT. WPN.    ORD.     FZ.    DISTRB. MOF.  MOC.      OT DIR.
:  MIL;:            ;:     ;:       ;:       ;:     ;:     ;  :    ;:         ;:   MIL;:

RQNO.   DTG.
      ;:XXXXXXXX;
```

MESSAGE TYPE 5

```
FORDRM.
 FR.   TO.   WCAT. TGT NO. RQNO.   GRID.              ALT.   MOC.     MOF.  METH EN
:    ;:    ;:    ;:      ;:      ;:                ;:      ;:       ;:    ;:

G.    DISTRB. OPN FIR. UADJ.        RDS.   ORD.    FZ.   LOT. CHG. ANGLE. TOT.
    ;:     ;  :     ;  :          ;:     ;:      ;:    ;:  ; : ;  :  ;    :

  UFFE.          RDS.   ORD.    FZ.   LOT. CHG. ANGLE. GTAZ.  UFFE.        RDS.
;:             ;:     ;:      ;:    ;:  ; : ;  :  ;    :     ;:           ;:

  ORD.    FZ.   LOT. CHG. ANGLE. GTAZ.   UFFE.        RDS.   ORD.    FZ.   LOT.
;:      ;:    ;:  ; : ;  :  ;    :     ; :          ;:     ;:      ;:    ;:  ;

 CHG. ANGLE. GTAZ.  DTG.
: ;   :  ;    :     ;:XXXXXXXX;
```

FORMAT 3: MESSAGE TYPE 1

```
CHKFIM:
FR........:
TO........:
TGT NO....:
RQNO......:
DTG.......:XXXXXXXX;
```

MESSAGE TYPE 2

```
EOMBDM:
FR.........:
TO.........:
TGT NO.....:
RQNO.......:
CAS........:
%DEST......:
ENMY PSTR..:
DTG........:XXXXXXX;
```

```
MESSAGE TYPE 3

TGTLST
FR.........:
TO.........:
GRID.......:
ALT........:
TTYP.......:
SIZE.......:
ATT........:
DOP........:
QTY........:
CLAS.......:
PRI........:
STATUS.....:
DTG........:XXXXXXXX;
```

```
MESSAGE TYPE 4

CFFTGR
FR.........::
TO.........:
TGT NO.....:
TTYP.......:
QTY........:
SIZE.......:
DOP........:
TGT MOV....:
AD.........:
DTOT.......:
ATT........:
METH ENG...:
WCAT.......:
WPN........:
ORD........:
FZ.........:
DISTRB.....:
MOF........:
MOC........:
OT DIR.....:
RQNO.......:
DTG........:XXXXXXXX;
```

```
MESSAGE TYPE 5

FORDRM
FR.........:
TO.........:
WCAT.......:
TGT NO.....:
RQNO.......:
GRID.......:
ALT........:
MOC........:
MOF........:
METH ENG...:
DISTRB.....:
OPN FIR....:
UADJ.......:
RDS........:
FZ.........:
LOT........:
CHG........:
ANGLE......:
TOT........:
UFFE.......:
RDS........:
ORD........:
FZ.........:
LOT........:
CHG........:
ANGLE......:
TOT........:
UFFE.......:
RDS........:
ORD........:
FZ.........:
LOT........:
CHG........:
```

```
ANGLE......:
GTAZ.......:
UFFE.......:
RDS........:
ORD........:
FZ.........:
LOT........:
CHG........:
ANGLE......:
GTAZ.......:
DTG........:XXXXXXXX;


FORMAT 4: MESSAGE TYPE 1

CHKFIM:
    FR:    ;                TO:    ;              TGT NO:       ;
  RQNO:      ;             DTG:XXXXXXXX;


          MESSAGE TYPE 2

    EOMBDM:
        FR:    ;            TO:    ;              TGT NO:       ;
      RQNO:      ;         CAS:      ;             %DEST:   ;
 ENMY PSTR:    ;           DTG:XXXXXXXX;


          MESSAGE TYPE 3
TGTLST:
    FR:    ;                TO:    ;                GRID:           ;
   ALT:     ;             TTYP:     /      ;        SIZE:   X   M;
   ATT:  MIL;              DOP:      ;               QTY:      ;
  CLAS: ;                  PRI: ;                 STATUS:    ;
   DTG:XXXXXXXX;
```

MESSAGE TYPE 4

```
CFFTGR:
    FR:    ;                 TO:    ;            TGT NO:      ;
  TTYP:     /     ;         QTY:      ;            SIZE:  X   M;
   DOP:     ;           TGT MOV:       ;             AD:  ;
  DTOT:    ;                ATT:  MIL;         METH ENG:           ;
  WCAT:    ;                WPN:       ;            ORD:      ;
    FZ:    ;             DISTRB:    ;               MOF:    ;
   MOC:       ;          OT DIR:   MIL;            RQNO:      ;
   DTG:XXXXXXXX;
```

MESSAGE TYPE 5

```
FORDRM:
        FR:    ;             TO:    ;              WCAT:    ;
    TGT NO:      ;         RQNO:      ;            GRID:          ;
       ALT:     ;           MOC:       ;            MOF:    ;
 METH ENG:          ;    DISTRB:    ;          OPN FIR:    ;
      UADJ:         ;       RDS:    ;               ORD:      ;
        FZ:    ;            LOT:  ;                 CHG: ;
     ANGLE:  ;              TOT:     ;             UFFE:            ;
       RDS:    ;            ORD:      ;              FZ:    ;
       LOT:  ;              CHG: ;                ANGLE:  ;
      GTAZ:    ;           UFFE:           ;        RDS:    ;
       ORD:      ;           FZ:    ;               LOT:  ;
       CHG:  ;            ANGLE:  ;                GTAZ:    ;
      UFFE:         ;       RDS:    ;               ORD:      ;
        FZ:    ;            LOT:  ;                 CHG: ;
     ANGLE:  ;             GTAZ:    ;               DTG:XXXXXXXX;
```

APPENDIX B: MESSAGE INPUT STIMULI

MESSAGE TYPE 1

Field Name	Abbreviation	Requested Entry
Check Fire Msg.	CHKFIM;	
From	FR:	AR61
To	TO:	BC30
Target Number	TGT NO:	BD2121
Request Number	RQNO:	162310
Date Time Group	DTG:	XXXXXXXX

MESSAGE TYPE 2

Field Name	Abbreviation	Requested Entry
End of Mission Battle Damage	EOMBDM;	
From	FR:	AA31
To	TO:	BA20
Target Number	TGT NO:	BB0100
Request Number	RQNO:	210000
Casualties	CAS:	00025
% Destroyed	%DEST:	99
Enemy Posture	ENMY PSTR:	Burn
Date Time Group	DTG:	XXXXXXXX

MESSAGE TYPE 3

Field Name	Abbreviation	Requested Entry
Target List Input	TGTLST;	
From	FR:	CA35
To	TO:	AC40
UTM Location	GRID:	DE64022610
Altitude	ALT:	00045
Target Type/Subtype	TTYP:	CEN /BN
Size	SIZE:	100X100
Attitude	ATT:	08
Degree of Protection	DOP:	HV
Quantity	QTY:	1
Target Priority	PRI:	1
Target Status	STATUS:	CONF
Date Time Group	DTG:	XXXXXXXX

MESSAGE TYPE 4

Field Name	Abbreviation	Requested Entry
Call for Fire by Target Number	CFFTGR;	
From	FR:	AG31
To	TO:	AG20
Target Number	TGT NO:	MT0732
Target Type/Subtype	TTYP:	VEH /ACFT
Quantity	QTY:	5
Size	SIZE:	200X200
Degree of Protection	DOP:	MDM
Target Mobility	TGT MOV:	STAT
Attitude	ATT:	10
Method of Engagement	METH ENG:	AREA
Weapon Category	WCAT:	AIR
Weapon	WPN:	2000
Ordnance	ORD:	BMBLT
Fuze	FZ:	Q
Distribution	DISTRB:	LAT
Method of Fire	MOF:	CONT
Method of Control	MOC:	FFE
Observer Target Direction	OT DIR:	018
Request Number	RQNO:	012116
Date Time Group	DTG:	XXXXXXXX

MESSAGE TYPE 5

Field Name	Abbreviation	Requested Entry
Fire Order Universal	FORDRM;	
From	FR:	EC10
To	TO:	AE00
Weapon Category	WCAT:	ARTY
Target Number	TGT NO:	BR2361
Request Number	RQNO:	390061
UTM Coordinates	GRID:	DE65022500
Altitude	ALT:	00020
Method of Control	MOC:	ADJ
Method of Engagement	METH ENG:	MRK/HA
Distribution of Fire	DISTRB:	ZN
Time to Open Fire	OPN FIR:	0600
Adjusting Unit	UADJ:	G/3/10
Number of Adjusting Rounds	RDS:	00003
Adjusting Ordnance	ORD:	HE
Adjusting Fuze	FZ:	Q
Adjusting Lot	LOT:	XY
Adjusting Charge	CHG:	4
Adjusting Angle	ANGLE:	26
Adjusting Time on Target	TOT:	0640
Fire for Effect Unit	UFFE:	H/3/10
FFE No. of Rounds	RDS:	00004
FFE Ordnance	ORD:	ICM

Field Name	Abbreviation	Requested Entry
FFE Fuze	FZ:	TI
FFE Lot	LOT:	TW
FFE Charge	CHG:	3
FFE Angle	ANGLE:	16
FFE Gun Target Line	GTAZ:	3200
FFE Unit	UFFE:	I/3/10
FFE No. of Rounds	RDS:	00006
FFE Ordnance	ORD:	SMKRED
FFE Fuze	FZ:	TI
FFE Lot	LOT:	YX
FFE Charge	CHG:	5
FFE Gun Target Line	GTAZ:	1800
FFE Unit	UFFE:	K/3/10
FFE No. of Rounds	RDS:	00002
FFE Ordnance	ORD:	WP
FFE Fuze	FZ:	VT
FFE Lot	LOT:	TE
FFE Charge	CHG:	2
FFE Angle	ANGLE:	24
FFE Gun Target Line	GTAZ:	4000
Date Time Group	DTG:	XXXXXXXX

APPENDIX C: DATA FOR PARAMETRIC ANALYSES

SPEED OF DATA ENTRY

S	Message Type									
	1		2		3		4		5	
	A	B	A	B	A	B	A	B	A	B
Format 1										
1	19	15	37	59	54	55	114	102	189	179
2	20	17	39	41	63	118	119	116	205	172
3	21	26	41	32	131	69	98	194	208	267
4	29	27	58	60	64	90	141	133	275	276
5	34	34	105	51	96	87	183	169	314	306
6	22	20	48	40	74	72	175	111	243	236
7	25	29	58	44	64	85	125	147	227	279
8	29	26	58	48	68	81	136	138	218	246
Format 2										
1	38	23	37	45	63	60	144	111	229	196
2	84	23	42	34	65	63	180	117	243	234
3	23	18	41	28	81	58	136	114	215	203
4	31	30	52	39	85	72	143	129	236	267
5	79	32	47	37	77	96	186	152	330	388
6	40	38	37	28	51	64	122	85	241	228
7	43	34	69	42	80	95	164	153	386	352
8	38	31	125	47	93	88	198	171	323	341

SPEED OF DATA ENTRY

S	Message Type									
	1		2		3		4		5	
	A	B	A	B	A	B	A	B	A	B
Format 3										
1	25	21	28	28	57	57	88	171	181	222
2	20	19	31	28	89	58	92	89	177	209
3	45	23	29	27	63	81	113	107	255	253
4	24	26	38	31	72	76	114	129	217	228
5	30	25	54	40	77	83	154	135	262	311
6	17	20	32	24	54	52	116	91	192	220
7	29	27	48	46	86	73	185	146	316	266
8	40	31	51	48	77	82	155	140	324	266
Format 4										
1	20	18	26	28	50	51	82	87	193	234
2	17	18	23	26	53	61	88	91	170	280
3	54	31	38	34	85	82	162	146	234	209
4	32	31	42	40	57	78	137	133	249	232
5	33	30	39	40	90	111	123	149	267	307
6	24	23	33	33	56	72	116	101	239	228
7	29	28	41	49	74	67	145	120	242	238
8	39	37	42	46	72	73	148	135	250	224

ACCURACY OF DATA ENTRY

ERRORS

S	Message Type									
	1		2		3		4		5	
	A	B	A	B	A	B	A	B	A	B
Format 1										
1				1						
2			1	1		1		1		
3			1				1			1
4				1						
5			1	1		1	1	1		1
6			1	1	1		1			
7			1	1			1			
8			1	1					1	
Format 2										
1		1		1					1	
2			1				1		1	
3					1	1			3	2
4						1				1
5	1								1	
6								1		1
7									1	
8			1			3			1	

ERRORS

ACCURACY OF DATA ENTRY

S	Message Type									
	1		2		3		4		5	
	A	B	A	B	A	B	A	B	A	B
Format 3										
1		1						1		
2					1					
3	1				1		1		1	
4										
5										
6						1		1		
7							1		1	
8							1			
Format 4										
1			1							1
2									1	1
3										
4										
5										
6					2		1	2		
7										1
8										

APPENDIX D: NORMALIZED TEST DATA

SPEED OF DATA ENTRY

S	Message Type									
	1		2		3		4		5	
	A	B	A	B	A	B	A	B	A	B
Format 1										
1	.731	.577	.925	1.475	.871	.887	.934	.936	.883	.840
2	.769	.654	.975	1.025	1.016	1.903	.975	1.064	.958	.806
3	.808	1.000	1.000	.800	2.047	1.030	.951	1.796	1.050	1.181
4	1.115	1.038	1.415	1.500	1.000	1.343	1.369	1.231	1.389	1.221
5	1.308	1.308	2.561	1.275	1.500	1.299	1.777	1.565	1.586	1.354
6	.846	.769	1.171	1.000	1.156	1.075	1.699	1.028	1.227	1.044
7	.962	1.115	1.450	1.100	1.032	1.371	1.025	1.349	1.061	1.310
8	1.115	1.000	1.450	1.700	1.097	1.036	1.115	1.266	1.019	1.155
Format 2										
1	1.407	.852	.925	1.154	.984	.896	1.412	1.037	1.157	.867
2	3.111	.852	1.050	.872	1.016	.940	1.765	1.093	1.227	1.035
3	.852	.667	1.025	.718	1.266	.866	1.333	1.065	1.086	.898
4	1.148	1.111	1.300	1.000	1.328	1.075	1.402	1.206	1.192	1.181
5	2.926	1.185	1.175	.949	1.203	1.433	1.824	1.421	1.667	1.717
6	1.481	1.407	.925	.718	.797	.955	1.196	.794	1.217	1.009
7	1.593	1.259	1.725	1.077	1.250	1.418	1.608	1.430	1.950	1.558
8	1.407	1.148	3.125	1.205	1.453	1.313	1.941	1.598	1.631	1.509

SPEED OF DATA ENTRY

S	Message Type									
	1		2		3		4		5	
	A	B	A	B	A	B	A	B	A	B
Format 3										
1	.962	.808	.718	.718	.919	.919	.727	1.583	.846	1.042
2	.769	.731	.795	.718	1.435	.935	.760	.824	.827	.981
3	1.731	.885	.744	.692	1.016	1.306	.934	.991	1.192	1.188
4	.923	1.000	.974	.795	1.161	1.226	.942	1.194	1.014	1.070
5	1.154	.962	1.385	1.026	1.242	1.339	1.273	1.250	1.224	1.460
6	.654	.769	.821	.615	.871	.839	.957	.843	.897	1.033
7	1.115	1.038	1.231	1.179	1.387	1.177	1.529	1.352	1.477	1.249
8	1.538	1.192	1.308	1.231	1.242	1.323	1.281	1.296	1.514	1.249
Format 4										
1	.769	.692	.650	.718	.781	.761	.804	.813	.995	1.054
2	.654	.692	.575	.667	.828	.910	.863	.850	.876	1.261
3	2.077	1.192	.974	.872	1.371	1.323	1.339	1.352	1.114	.995
4	1.231	1.192	1.077	1.026	.919	1.258	1.132	1.231	1.186	1.105
5	1.269	1.154	1.000	1.026	1.452	1.790	1.017	1.380	1.271	1.462
6	.923	.885	.846	.846	.903	1.161	.959	.935	1.138	1.086
7	1.115	1.077	1.025	1.256	1.156	1.000	1.422	1.121	1.247	1.072
8	1.500	1.423	1.050	1.179	1.125	1.090	1.451	1.262	1.289	1.009

ERRORS

ACCURACY OF DATA ENTRY

S	Message Type									
	1		2		3		4		5	
	A	B	A	B	A	B	A	B	A	B
Format 1										
1	0	0	0	.143	0	0	0	0	0	0
2	0	0	.143	.143	0	.083	0	.048	0	0
3	0	0	.143	0	0	0	.048	0	0	.023
4	0	0	0	.143	0	0	0	0	0	0
5	0	0	.143	.143	0	.083	.048	.048	0	.023
6	0	0	.143	.143	.083	0	.048	0	0	0
7	0	0	.143	.143	0	0	.048	0	0	0
8	0	0	.143	.143	0	0	0	0	.023	0
Format 2										
1	0	.25	0	.143	0	0	0	0	.023	0
2	0	0	.143	0	0	0	.048	0	.023	0
3	0	0	0	0	.083	.083	0	0	.069	.046
4	0	0	0	0	0	.083	0	0	0	.023
5	.25	0	0	0	0	0	0	0	.023	0
6	0	0	0	0	0	0	0	.048	0	.023
7	0	0	0	0	0	0	0	0	.023	0
8	0	0	.143	0	0	.249	0	0	.023	0

ACCURACY OF DATA ENTRY

ERRORS

S	Message Type									
	1		2		3		4		5	
	A	B	A	B	A	B	A	B	A	B
Format 3										
1	0	.25	0	0	0	0	0	.048	0	0
2	0	0	0	0	.083	0	0	0	0	0
3	.25	0	0	0	.083	0	.048	0	.023	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	.083	0	.048	0	0
7	0	0	0	0	0	0	.048	0	.023	0
8	0	0	0	0	0	0	.048	0	0	0
Format 4										
1	0	0	.143	0	0	0	0	0	0	.023
2	0	0	0	0	0	0	0	0	.023	.023
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	.166	0	.048	.096	0	0
7	0	0	0	0	0	0	0	0	0	.023
8	0	0	0	0	0	0	0	0	0	0

APPENDIX E: INTERACTION TABLES

SPEED OF DATA ENTRY

AXBXC

C/B	1					2				
	1	2	3	4	5	1	2	3	4	5
1	1.308	2.400	1.758	1.870	1.723	2.259	2.079	1.880	2.449	2.024
2	1.423	2.000	2.919	2.039	1.764	3.963	1.922	1.956	2.858	2.262
3	1.808	1.800	3.077	2.747	2.231	1.519	1.743	2.132	2.398	1.984
4	2.153	2.915	2.343	2.600	2.610	2.259	2.300	2.403	2.608	2.373
5	2.616	3.836	2.799	3.342	2.940	4.111	2.124	2.636	3.245	3.384
6	1.615	2.171	2.231	2.727	2.271	2.888	1.643	1.752	1.990	2.226
7	2.077	2.550	2.403	2.374	2.371	2.852	2.802	2.668	3.038	3.508
8	2.115	3.150	2.133	2.381	2.174	2.555	4.330	2.766	3.539	3.140

C/B	3					4				
	1	2	3	4	5	1	2	3	4	5
1	1.770	1.436	1.838	2.310	1.888	1.461	1.368	1.542	1.617	2.049
2	1.500	1.513	2.370	1.584	1.808	1.346	1.242	1.738	1.713	2.137
3	2.616	1.436	2.322	1.925	2.380	3.269	1.846	2.694	2.691	2.109
4	1.923	1.769	2.387	2.136	2.084	2.423	2.103	2.177	2.363	2.291
5	2.116	2.411	2.581	2.523	2.684	2.423	2.026	3.242	2.397	2.733
6	1.423	1.436	1.710	1.800	1.930	1.808	1.692	2.064	1.894	2.224
7	2.153	2.410	2.564	2.881	2.726	2.192	2.281	2.156	2.543	2.319
8	2.730	2.539	2.565	2.577	2.763	2.923	2.229	2.215	2.713	2.298

AXB

B/A	1	2	3	4
1	15.115	22.406	16.231	17.845
2	20.822	18.943	14.950	14.787
3	19.663	18.193	18.337	17.828
4	20.080	22.125	17.736	17.931
5	18.084	20.901	18.263	18.160

AXC

C/A	1	2	3	4
1	9.059	10.691	9.242	8.037
2	10.145	12.961	8.775	8.176
3	11.663	9.776	10.679	12.609
4	12.621	11.943	10.299	11.357
5	15.533	15.500	12.315	12.821
6	11.015	10.499	8.299	9.682
7	11.775	14.868	12.734	11.491
8	11.953	16.330	13.174	12.378

BXC

C/B	1	2	3	4	5
1	6.798	7.283	7.018	8.246	7.684
2	8.232	6.677	8.983	8.194	7.971
3	9.212	6.825	10.225	9.761	8.704
4	8.758	9.087	9.310	9.707	9.358
5	11.266	10.397	11.258	11.507	11.741
6	7.734	6.942	7.757	8.411	8.651
7	9.274	10.043	9.791	10.836	10.924
8	10.323	12.248	9.679	11.210	10.375

AXBXC ACCURACY OF DATA ENTRY

C/B	1					2				
	1	2	3	4	5	1	2	3	4	5
1		.143				.250	.143			.023
2		.286	.083	.048			.143		.048	.023
3		.143		.048	.023			.166		.115
4		.143						.083		.023
5		.286	.083	.096	.023	.250				.023
6		.286	.083	.048					.048	.023
7		.286		.048						.023
8		.286			.023		.143	.249		.023

C/B	4					5				
	1	2	3	4	5	1	2	3	4	5
1	.250			.048			.143			.023
2			.083							.046
3	.250		.083	.048	.023					
4										
5										
6			.083	.048				.166	.144	
7				.048	.023					.023
8				.048						

AXB

B/A	1	2	3	4
1		.500	.500	
2	1.859	.429		.143
3	.249	.498	.249	.166
4	.288	.096	.240	.144
5	.069	.276	.046	.092

AXC

C/A	1	2	3	4
1	.143	.416	.298	.166
2	.417	.214	.083	.046
3	.214	.281	.404	
4	.143	.106		
5	.488	.273		
6	.417	.071	.131	.310
7	.334	.023	.071	.023
8	.309	.415	.048	

BXC

C/B	1	2	3	4	5
1	.500	.429		.048	.046
2		.429	.166	.096	.069
3	.250	.143	.249	.096	.161
4		.143	.083		.023
5	.250	.286	.083	.096	.046
6		.286	.332	.288	.023
7		.286		.096	.069
8		.429	.249	.048	.046

APPENDIX F: NONPARAMETRIC ANALYSIS

EASE OF USE

	1		2		3		4	
Subj.	S	R	S	R	S	R	S	R
1	3	1	6	4	4	2	5	3
2	10	2	14	4	10	2	10	2
3	3	3	15	4	0	1	2	2
4	10	2	13	4	10	2	10	2
5	10	3	15	4	4	1	7	2
6	5	3	15	4	1	1	4	2
7	10	3.5	10	3.5	0	1.5	0	1.5
8	10	2.5	15	4	5	1	10	2.5
$\sum_{i=1}^{8} R_{ij}$		20		31.5		11.5		17

$$\chi_r^2 = \frac{12}{nk(k+1)} \left[\sum_{j=1}^{k} \left(\sum_{i=1}^{n} R_{ij} \right)^2 \right] - 3n(k+1)$$

$$= \frac{12}{8(4)(4+1)} [400 + 992.25 + 132.25 + 289] - 3(8)(4+1)$$

$$= 15.96^*$$

$$\chi^2_{0,05,3} = 7.82$$

SUITABILITY

Subj.	1		2		3		4	
	S	R	S	R	S	R	S	R
1	4	1	6	4	5	2.5	5	2.5
2	8	1	14	4	9	2	11	3
3	15	3.5	15	3.5	0	1	5	2
4	13	3	14	4	9	1	11	2
5	9	3	14	4	3	1	4	2
6	10	3.5	10	3.5	1	1	5	2
7	5	3	5	3	5	3	0	1
8	5	1.5	15	4	5	1.5	10	3
$\sum_{i=1}^{8} R_{ij}$		19.5		30		13		17.5

$$\chi_2^2 = \frac{12}{8(4)(5)} [380.25 + 900 + 169 + 306.25] - 3(8)(5)$$

$$= 11.64*$$

$$\chi^2_{0,05,3} = 7.82$$

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13. ABSTRACT

The purpose of this thesis is to determine if format variation has any affect on speed and accuracy of data entry for the Marine Integrated Fire and Air Support System (MIFASS).

Independent variables for the test are message formats, message types, and subjects. Subject learning effects and experimenter differences are controlled by use of a pilot study. Subjects are included as a treatment in order to estimate their effects.

The experiment is designed to support both parametric and nonparametric analyses. A 4x5x8 randomized complete block factorial with two replications is used to analyse the effects of format variation. Friedman's Two-Way ANOV by Ranks is used to test subjective rankings of the formats as concerns ease of use and operational suitability.

It is concluded that format variations do affect speed of data entry but not accuracy. Format 3 appears to be superior. Recommendations for further study are given.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
MIFASS						
FORMAT VARIATION						
MESSAGE TYPE						
RANDOMIZED COMPLETE BLOCK						
FACTORIAL						

Laney

The effect of format variation on data entry speed and accuracy for the Marine Integrated Fire and Air Support System (MIFASS).

Thesis
L262
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